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A REVIEW OF THE 1979 WORKSHOP ON THERMOMECHANICAL  
MODELING FOR A HARD ROCK WASTE REPOSITORY

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# A REVIEW OF THE 1979 WORKSHOP ON THERMOMECHANICAL MODELING FOR A HARD ROCK WASTE REPOSITORY

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## SUMMARY

The 1979 Workshop discussed and considered issues and needs in the areas of Modeling, Laboratory Measurements, Instruments and Field Measurements, and In-situ Tests and Model Validation. A set of conclusions and recommendations was developed, which focused on the necessity of treating the rock mass response to the waste emplaced in it. The conclusions dealt with characterizing the fracture system, determining the mechanical and thermal properties, developing an understanding of the physical process, predicting and measuring the response, and carrying out meaningful validation tests. Measured against the stated objectives, the 1979 Workshop was successful. With respect to implementation of its recommendations, this conclusion is not so obvious, although some activities of the past year suggest the Workshop has had a beneficial influence.

## INTRODUCTION

I am pleased to give you a summary of the first Workshop on Thermomechanical Modeling for a Hard Rock Waste Repository which was held under the auspices of DOE's Office of Waste Isolation, (ONWI) and the Lawrence Livermore National Laboratory in June, 1979. I will do this rather briefly for two reasons. First, many of you here today participated in that Workshop. Second, the proceedings are available and give the details of the recommendations and conclusions in a much more complete and satisfactory way than I can do here.

Our objectives were the following:

1) Identify the key issues connected with modeling and validating the response of a hard rock repository to the emplaced waste source.

2) Identify status and needs, and develop a list of recommended activities, in order of priority, which would serve as programmatic input to ONWI and DOE for future consideration and implementation.

Since the purpose of this summary is to provide a point of departure and a perspective for this present workshop, I will show where we have met (or missed) these objectives, and will also attempt to trace some of the progress made in the past year. In particular, I will try to point out where perhaps the efforts of the 1979 Workshop have made a contribution and where we have failed to make an impact.

Before listing our conclusions, I believe it is pertinent to point out similarities as well as differences between the 1979 Workshop and our present meeting. The similarities are fairly obvious. The organization is about the same, consisting of a series of papers des-

cribing the status of ongoing activities in a number of research areas, followed by a series of workshop discussion groups dealing with issues, shortcomings, needs, and recommended actions. The discussion group titles read very much the same, although in our present meeting consideration of instrumentation is combined with field experiments, while in our past meeting they were treated separately. The major differences appear to be including the consideration of salt as a waste medium, and hydrologic and hydrochemical phenomena in the present workshop. These additions may give a different flavor to our present meeting, and will certainly lead to expanded conclusions.

## 1979 WORKSHOP CONCLUSIONS AND RECOMMENDATIONS

A common theme was voiced by all the workshop groups, and indeed by the whole meeting. This was "concentrate on the rock mass". Table 1 lists the main needs identified as requiring attention.

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Table 1. Concentrate on Rock Mass

- o Determine its thermal and mechanical properties,
  - o Characterize the nature and extent of the fracture system,
  - o Develop instruments specially tailored to measure rock mass response,
  - o Model its behavior, concentrating on constitutive relations dealing with discrete and ubiquitous fractures.
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As expected, the main feature of concern was the role that fractures and discontinuities play, how to characterize this role, how to measure it, and how to predict it. These points will become more obvious in the conclusions and recommendations of the individual workshop groups, which I now want to briefly summarize. Again, let me urge you to read the proceedings for the full details.

Table 2 gives the highlights of the points made by the Codes and Modeling group.

It is interesting to note that, within the limits of thermomechanical considerations only, the participants did not feel that code development was a primary issue; emphasis was placed on the physics, i.e., the model. Not listed on Table 2 were suggestions made for closer interactions among the members of the modeling community, increased attention to training of analysts, and more public awareness of the role of models in waste isolation.

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Table 2. Codes and Modeling

- Need better constitutive relations to describe
    - o ubiquitous and discrete fractures
    - o rock failure
    - o permeability - fracture interdependence
    - o scaling effects
    - o anisotropic effects
  - Need more sensitivity studies
    - o to guide experiments
    - o to set boundaries
  - Need more than one code for particular situations
    - o simple codes for scoping
    - o more complex ones to handle coupled problems
- 

Table 3 summarizes the conclusions of the Laboratory Measurements Workshop Group. Notice that the item of first priority is the characterization of the the rock mass. Only secondly the need for a careful feasibility examination of a large sample testing facility was recommended.

Table 4 shows how people felt about the state of instruments and measurements. I believe it is fair to say that they identified a need for evolutionary, rather than revolutionary, development.

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Table 3. Laboratory Measurements

- Develop methods to characterize fractures
    - o by electrical, acoustical, or other indirect sensing methods
    - o by mapping
  - Begin a feasibility study of a laboratory facility able to test one-meter size samples
    - o capability to 300C, 100 MPa pore and confining pressure
    - o investigate scale effects on fractured samples
    - o determine physical/thermal/hydraulic properties
  - Accelerate measurements on smaller intact and fractured samples
    - o failure, creep, deformation
    - o fluid and thermal transport properties
- 

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Table 4. Field Measurements and Instrumentation

- Need better instruments for stress and displacement measurements
    - o improved extensometers and stress gages
    - o new techniques such as jack tests need further development
  - Develop monitoring techniques for changes in the frequency, nature, and geometry of fractures with time
  - Better methods for measuring in situ stress are needed
    - o hydrofrac techniques
    - o acoustic
    - o gages
  - Develop better methods to measure rock mass fluid transport properties
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I have attempted to summarize the recommendations of the In-Situ Testing and Model Validation Workshop in Table 5. This group considered the broader issues of definitions, needs, and rationale - in effect synthesizing the considerations of the whole meeting. A simple table cannot do justice to their conclusions.

At this point it is fair to ask to what extent we met the objectives of the 1979 Workshop. All of those who identified the issues, developed the recommendations, and indicated the priorities, believed that a fair and fairly complete job, within the limitations of time and scope, had been done. From the standpoint of communicating and focusing on problems, I believe all the participants felt quite good about the effort spent, and if success is defined as meeting one's objectives, the 1979 Workshop can be termed a success.

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Table 5. In-Situ Testing and Model Validation

Need to give more thought to and do more detailed planning on future in-situ experiments

In-situ tests must be designed with a clear understanding of what constitutes "validation":

- o ability to predict near and far field effects based on understanding of physical processes
- o large enough size (about 3 repository rooms) and long enough (about 10 years)
- o measurements with reasonable accuracy and resolution
- o peer and public acceptance is an integral part

Need to do more tests in tuff and shales

Carefully examine cost effectiveness of future tests using radioactive sources as compared to those with electric heaters only.

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The payoff, however, must also be judged by the degree to which our recommendations have been followed and implemented. From that criterion, it is not quite so obvious that the label "successful" can be applied. In order to judge this matter, I have tried to examine those areas that may have been influenced either directly or indirectly by the 1979 Workshop. Obviously, most of the activities that are now going on in the rock mechanics field as they apply to waste isolation in crystalline media would have proceeded if the 1979 workshop had not been held. The set of papers which follow later in the present program will describe the progress that has been made in basalt, granite, and tuff. These activities have had the effect of calling increased attention to the properties of media other than salt. I would like to think that the 1979 Workshop contributed to the increasing emphasis and support for in-situ experiments and investigations that

focus on the rock mass issues inherent to these media.

One other development which took place during the past year and is closely related to both the 1979 and 1980 Workshops is the production and imminent publication of a Rock Mechanics R&D Technical Plan.<sup>2</sup> This plan was written by the Rock Mechanics Subgroup of the Earth Sciences Technical Plan Working Group, many of whose members participated actively in the 1979 Workshop. The four main technical elements of the portion of the plan dealing with generic issues bear a strong similarity to the 1979 and 1980 Workshop topics; they are:

- 1) Rock mass characterization
- 2) Modeling
- 3) In-situ testing
- 4) Repository design

In addition to treating repository design, the Rock Mechanics Plan discusses the other topics in considerably greater detail than we were able to do in the 1979 Workshop and, I suspect, in greater depth than is possible to do in the present meeting. The plan also goes beyond the 1979 Workshop in addressing the coupling between mechanical, thermal, and hydraulic phenomena and stresses the importance of these interactions. While building on a number of the conclusions of the 1979 Workshop, this plan expands on many of them.

The Rock Mechanics Plan also presents specifics for tests in granite, basalt, tuff, and shales. It thus begins to address a topic which, in retrospect, I feel we neglected in the 1979 Workshop. It can be simply stated in the following way: given a potential repository site, what are the rock mechanics questions that must be answered before it can be confidently identified as meeting all criteria? A continuous process is most likely involved in such an identification. The time scale, however, may have to be drastically shortened if recent legislative proposals are carried out and become law. A consequence of the perceived slow and deliberate rate of progress in waste isolation research is the impatience by some members of Congress who want to "get on with it". We may see more bills introduced similar to the Nuclear Waste Research, Development, and Demonstration Act of 1980,<sup>3</sup> which not only mandates programs on a seemingly impossible short time scale, but also specifies technical details such as maximum permissible temperatures, number and types of canisters, and number and types of media. The implications are clear, and lead me to voice a recommendation made last year which I am confident will be repeated this year: progress needs to be accelerated, and recommendations implemented.

## References

- 1) Proceedings of a Workshop on Thermo-mechanical Modeling for a Hardrock Waste Repository, ONWI-98, UCAR-10043, Office of Nuclear Waste Isolation, June 25-27, 1979, Berkeley, CA.
- 2) NWTS Rock Mechanics R&D Technical Plan for Mined Geologic Disposal of Radioactive Waste, by DOE/USGS/ESTP/Rock Mechanics Subgroup of DOE/USGS Earth Science Technical Plan Working Group, to be published.
- 3) "Nuclear Waste Research, Development, and Demonstration Act of 1980", report to accompany H.R. 7418, dated June 30, 1980.

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